Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	)	
	)	ET Docket No. 03-104
Carrier Current Systems, Including	)	
Broadband over Power Line Systems	)	
	)	
Amendment of Part 15 Regarding New	)	ET Docket No. 04-37
Requirements and Measurement Guidelines	)	
for Access Broadband	)	
over Power Line Systems	)	
	)	

To: The Commission
August 4, 2004

COMMENTS OF MARC A. RESSLER

Introduction

I hold a masters degree in electrical and computer engineering, and am a member of the Antennas and Propagation and Electromagnetic Compatibility Societies of IEEE. I held the FCC First Class Radiotelephone license at the time it was so designated. In my youth I was an avid shortwave listener and during my time as a member of the Civil Air Patrol, I was the squadron communications officer. I have been licensed as an amateur radio operator since 1960 and hold the Extra Class license. Over the years I have operated on every amateur band between 1.8 and 1300 MHz with the exception of the new 60-meter allocation and used AM, FM, CW, SSB, slow-scan TV, and digital modes during that time. In recent years I have spent much of my time operating at power levels of 5 watts or less (known as QRP to amateurs).[1] I am a member of QRP-ARCI (Amateur Radio Club International), and a life member of ARRL, AMSAT, and 10-X (an organization promoting the use of the 10 meter band). In short, I have a long-time interest in communications in the MF through UHF bands, so even though I do not live in a BPL test area, and have not had any direct experience with Access or In-House BPL interference, I am an interested party to these proceedings.

The FCC has issued an NPRM on the use and guidelines for the operation of Broadband over Power Lines (BPL) under the Part 15 rules. The fact that this proceeding has reached the stage where an NPRM has been issued implies to me the likelihood that some form of BPL will be permitted in the near future. These comments are in response to that NPRM as well as in reply to a number of respondents to the NOI and NPRM and are based on my reading of the proceedings and analysis of signal levels involved. The attached Technical Appendix is part of this filing.

[1] The viability of this mode is best demonstrated by the contact I made a few weeks ago with a station in Slovenia (distance 7150 km) using a homemade 1.5-watt transceiver.

Background
That these proceedings have been contentious is an understatement. In recent history, this proceeding is second only to that of the Do-Not-Call proceeding (02-278) in the sheer quantity of filings in a relatively short period of time. The proceeding is muddied by the fact that the modulation means, the duty cycles, the frequencies involved, the coupling methods to the power line, and the delivery method[2] to the customer are different for each manufacturer and in addition, very little quantitative technical information has been provided. There is not even agreement between the various proponents; one manufacturer[3] insists BPL injectors act as point sources, while another[4] insists they cannot.[5] While there have been attempts at modeling the fields surrounding the power lines, every time someone does so it is claimed to not be relevant because the industry doesn't couple power into lines that way – not that anyone has indicated exactly how they couple to the line[6]. The proponents of BPL claim that not only is there a low probability of interference[7], but that there have been no reports of (harmful) interference, while the ARRL has provided measurements and copies of reports detailing interference.[8]

Recently, the level of rhetoric has inflamed to the point that the UPLC has labeled me and my fellow FCC licensees as "…a misinformed set of armchair amateurs that still use vacuum tube transmitters"[9] while Progress feels those filing complaints "intentionally seek out interference using very sophisticated and sensitive equipment"[10]. In other words, amateurs are either dinosaurs on the verge of extinction or bleeding-edge techno-geeks. It was provocative statements like this that had me go back through the record of this proceeding to see where the middle ground lay. But first, let's put these two issues to bed. While accusing amateurs of using vacuum tubes may be good press, that's all it is. After all, if you have electricity in your home, you probably have a number of vacuum tubes – they're the CRTs in your TV or computer. I still own an HF transceiver with three tubes in it, but it is on loan to a newly licensed amateur, and it works just fine. And let us not forget all those other transmitters with vacuum tubes: in AM, FM, and TV broadcast stations, onboard satellites and in satellite earth stations, and in countless radars on the ground, in the air, and at sea. As to the sophisticated and sensitive equipment, it need be neither. The MF and HF bands are limited by atmospheric noise at the low end of the spectrum, and by man-made noise at the high end. Good receiver design calls for trading off sensitivity when it is not needed for improved strong-signal performance, and this is what most modern amateur transceivers provide. Because of this, my homemade 30-meter transceiver has

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[2] Some of the means mentioned are BPL on the LV lines (both HomePlug compliant and not) and wireless (802.11a/b/g).
[3] Current Technologies (AUG 2003) at 10, 11.
[4] Ameren (JUL 2003) at 16.
[5] For more discussion on this point, see the Technical Appendix.
[6] The choices are capacitive or inductive coupling, with options of differential drive between pairs of wires, or driving the line with respect to ground. The specific implementation may be different, and some means may be more efficient than others, but unless someone is concerned about patent rights or competitive advantage, it is unclear why this remains cloaked by the BPL proponents.
[7] For example, Progress (JUN 2004) called it low or non-existent, while HECO (JUL 2003 at 3-4) feels that if a device meets the Part 15 limits it will be non-interfering – see **Part 15 Issues**.
[8] City of Manassas, Virginia (JUN 2004) at 4 cites no interference, while private communications with OVH indicates they have filed interference complaints with the FCC and with the City; ARRL (AUG 2003) Exhibit A.
[9] UPLC Reply Comments of June 2004 at 32. I actually know an amateur who uses an old decrepit armchair at his operating position, and he does have a vacuum tube amplifier – he is also a retired electronics engineer.
[10] Progress (May 2004) at 8

sensitivity within 3 dB of my commercial transceiver, and it would have NO problem finding a signal that was at the 30-meter FCC limits[11]. Calls for restrictions or even punishment for "nuisance" interference reports are an over-reaction by proponents. The normal reaction of many amateurs to recurring interference is to identify the source and try to eliminate the problem. I once had to build a loop antenna and walk around my community to find the source of an intermittent, yet harmful, wideband interference source. The fact that amateurs that already have radios in their cars would drive around looking for the source of interference they experienced, either on the road or at home, does not surprise me.

The Amateur Service is very different from other FCC licensed services. Operators have a wide choice of power levels and frequencies to operate on and typically are not assigned to specific "channels". The amateur operator picks the frequency band of interest based on the prevailing propagation conditions of the moment to provide a certain probability of communications to a particular point in the country, or to another part of the world, and searches for signals from the target area, or an unoccupied frequency on which to initiate communications. At times, signals from overseas stations can be incredibly weak at times, barely above the background noise. Amateur stations are typically located in residential areas and thus their antennas will be close to nearby power lines. These antennas will range from simple dipoles at the lower frequencies to multiband verticals and rotatable yagi arrays at the higher frequencies. In areas serviced by overhead power lines, these antennas will typically be erected at heights above, or on the order of, the height of the service lines, and may easily be surrounded on three sides by power lines (the MV and LV lines across the front of the yard, the LV line to the home, and the LV line to the neighbor's home). It is this scenario that has amateur radio licensees frightened, because the distance from an antenna to an active BPL device or cable can easily be less than 30 meters. As pointed out by CEPT,[12] "Amateurs do not generally have the opportunity to position antennas far away from electric wiring. They must install their antennas within the boundaries of their homes, which generally means in close proximity to mains and telephone wiring".

Why BPL

There is no doubt that BPL can provide utility companies with an improved signaling method for monitoring the health of the power grid and thus improve the quality and reliability of electric power. BPL also holds the promise of providing broadband services to underserved locations and increasing competition in the broadband marketplace. However, it is unlikely that BPL will solve the problem of providing broadband to rural locales any time soon.[13] BPL is not the only solution and comments about the broadband "duopoly" are largely the result of the previous regulatory environment. The Administration's[14] proposals for providing broadband to all of the country by 2007 include, amongst other things, economic incentives to encourage capital expenditures, releasing fiber-to-home from legacy regulations, streamlining federal rights-of-way approvals to build high speed infrastructure, and the release of federal spectrum for wireless services. Arguments as to the economic viability of any of these, and other, alternate broadband approaches are the same for arguments about BPL's viability – not germane to this topic and

[11] See Technical Appendix.
[12] CEPT: ECC Report 24, "PLT, DSL, Cable Communications (Including Cable TV), LANS and Their Effect on Radio Services", May 2003, at 27
[13] Joint Comments Of The National Rural Telecommunications Cooperative And The National Rural Electric Cooperative Association (MAY 2004) at 2 and 8.
[14] The White House, "A New Generation Of American Innovation", April 2004

something the marketplace will decide. The asymmetric nature of DSL and cable broadband is based on economic models, and even now symmetric DSL is available. There is nothing that makes BPL inherently symmetric, nor is there a guarantee that all BPL systems will remain symmetric.

There are also claims of BPL enhancing homeland security[15] but should this be done at the expense of RF-based emergency communications? The Part 97 rules[16] recognize the ability of amateurs to provide communications in an emergency, and emergency operations are codified in subsection E of that part. It was amateur radio operators who provided communications support within minutes of the attacks of September 11th, when commercial communications systems were either overloaded or non-functioning since so many had been located on the top of the World Trade Center. These amateurs provided communications for weeks after this tragedy – all on a volunteer basis – and as they frequently do during natural disasters.

The NTIA[17] has declared BPL to be a "win-win" proposition because not only will the public benefit from the technology, but also because existing noise problems will likely be cleaned up as a necessity of supporting BPL. It has been pointed out that powerline noise is one of the most common complaints of amateur operators. However, replacing one type of interference for another is NOT an acceptable solution – powerline noise problems need to be handled as the violation of law that they are. And indications are that power companies are not prepared to make wholesale upgrades to the power distribution system just to support BPL.[18]

Part 15 issues

The Part 15 field strength levels have been developed to minimize the *probability* of interference between neighboring devices[19], not to eliminate the *possibility* that interference might occur. Given close enough spacing, devices that generate RF energy may cause interference. It is why the information to the user[20] on how to deal with interference is provided in the instruction manual. Thus I have discovered that I cannot leave my DVD player in the standby mode, but must turn it off completely, if I want to watch certain TV channels. Likewise, I must turn off my stereo system if I want to watch certain other TV channels, and I can't have the computer on if I want to watch TV in the bedroom. I also have discovered that I cannot mount my CD player directly over my cassette tape deck. These are a handful of the Part 15 issues I have had to personally deal with. These are issues *I* can resolve because *I* have direct control of the environment in which these devices operate and they are all Part 15 devices. The potential of interference is also why there is no cable TV routed to my house. The Commission has suggested[21] that the amateur need only point his antenna away from a source of interference to eliminate problems. The problems with this solution are: 1) most importantly, that it is not the amateur's problem, it's the interfering device's problem, 2) that not all antennas are rotatable, and those that are typically have a 60° beamwidth, and 3) if I'm trying to contact San Francisco,

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[15] Cinergy (JUL 2003)at 3, Current Technologies (JUL 2003) at 8, ITI (JUL 2003) at 2, NPRM at ¶48.
[16] §97.1
[17] NTIA (JUN 2004) at 4.
[18] Consolidated Edison (JUN 2004)
[19] Especially in residential settings. Note that the Class B emissions limits are much more strict than the Class A (commercial) limits.
[20] §15.105
[21] NPRM at ¶35.

CA (or Melbourne, Australia) and it is in the same direction as the interference, then I cannot improve the situation (more to the point, if I am surrounded by sources of interference, it may not matter which way I point).

Nothing in these proceedings has indicated that the FCC plans to lower the Part 15 levels[22], and I must assume that, barring some voluntary industry standard (such as the HomePlug Alliance) that most suppliers will use the maximum allowable power levels[23] at whatever frequencies they wish, especially since some are already asking to increase power in the future[24], as it will minimize the number of repeaters needed to maintain signal quality. The fact that proponents are asking for the *radiated* limits to be increased indicates that some are already running at those limits. This is not meant to indict the whole industry. The concern is not what any one proponent says they can do, or will do, that is the issue – it is what the rules might allow. The non-interference clause[25] is the ultimate limit, but should not be considered as a reasonable engineering design tool! It is what caused Phonex to redesign its model PX-421 wireless modem jacks that were causing interference in the vicinity of 3.52 MHz, but at who knows what expense.[26] What I am talking about is trying to design to the spirit of the law, not to the letter of the law.

Let me try to define some terms of reference. The problem is that *if* an amateur antenna is 30 meters or less from an Access BPL device that is emitting *at* the Part 15 *limits*, and *in* an amateur band, it *will* cause harmful interference and the range over which the interference is "harmful" extends beyond the 30 meter point.[27] This is why ARRL and NTIA[28] consider BPL to present a high *risk* of interference. Note that this does not mean that all BPL systems would be interfering, just that they could be if the above conditions are met. For instance, *if* there is *very little* energy radiated in a band, there will not be any interference, but if there is a 30µV/m field at 30 meters or less from an amateur antenna, there will be harmful interference.

The Access BPL industry in general seems to be opposed to *a priori* avoidance of the amateur, or any other, bands[29]. I don't understand this, given that the HomePlug Alliance has worked closely with amateurs to minimize the energy in amateur bands.[30] This cooperative effort has eliminated the kind adversarial situation that seems rife in these proceedings, although there are indications

[22] NPRM at ¶33 and ¶34.
[23] Current Technologies indicates they are operating at tens of dB below other providers (JUN 2004) at 20.
[24] Southern (JUN 2004) at 28, UPLC (JUN 2004) at 6-7, PowerComm (AUG 2003) at 15,16.
[25] §15.5 (b).
[26] The problem with the Phonex wireless jacks was first reported in the ARRL Letter, Vol. 17, No. 51/Vol. 18, No. 1 (December 25, 1998/January 1, 1999). Within days of receiving the first reports of problems, Phonex discontinued the PX-421 jack and redesigned it to operate outside the amateur bands. They also modified the design to eliminate transmitting a dead carrier when the unit is not in actual use. They immediately started a campaign to replace or re-tune existing units with new ones.
[27] See Technical Appendix.
[28] ARRL (AUG 2003) at 2, NTIA (JUN 2004) at 14
[29] However, Current Technology indicates it operates outside of the amateur bands and PowerWAN indicates it notches amateur frequencies. See also NPRM at ¶42.
[30] HomePlug & ARRL "Joint Test Report" JAN, 2001. Tests showed that with moderate separation between the antenna and the house that interference was barely perceptible. The tests were performed with simulated equipment, but similar tests with production units are reported by Koos Fockens in "HF radio reception compatibility test of an in-house PLC system using two brands of modems" VERON EMC Committee OCT 2003.

from some BPL proponents that they may have a close working relationship with amateurs in their local test area. Of course, one solution is to just legislate lower levels in certain bands. The Commission has chosen this approach in the past as demonstrated by §15.510 – §15.519. The Commission realizes that the "no interference" clause is unenforceable and has tried to craft regulations that will avoid the situation. What many proponents are asking for is to turn on their system and wait for complaints to come in, rather than trying to avoid them in the first place, and then try to solve the problem. We have already seen this does not always work for BPL.[31] What is worse is that we are now on the declining side of a sunspot cycle. This means that the activity rates on some frequency bands will increase while on others it will decrease at different times of the day. In about 5 years that trend will reverse as the next sunspot cycle begins to rise. Simple fixes applied to a situation now may be of little use in 5 years. What will be the cost (in dollars to the provider, in frustration to the amateur) to fix the problem then?

Proponents[32] have asked why BPL should be treated differently from any other unintentional emitter. After all, the NPRM stated carrier current systems have rarely been a source of harmful interference.[33] First, many Access BPL systems couple energy in an unbalanced method onto an MV line, generating a EM field between the line and the earth below, begging the question as to whether BPL should even be considered an unintentional radiator.[34] Second, BPL systems are wideband and at much higher frequencies than the low-speed carrier current systems the Commission mentioned. Third, it is not being installed IN my neighbor's home, but possibly throughout my community. In addition, I may no longer have control over the frequency bands on the wiring within my own home, but will be stuck with whatever is dictated by some local provider – *even when I have not signed up for service with them*.

Typical Part 15 devices may generate a low power carrier at one or more points in an amateur band (for instance, TV color-burst oscillators can be heard at 3.579 MHz at my location until very late at night) but I can tune away from them if they are too loud. With BPL, not only is there a prospect of not finding a clear spot anywhere in a band, but possibly not on any band! Let's face it; if there were no issue with the use of BPL within the context of current Part 15 regulations, there never would have been a need for an NOI. BPL proponents insist the power lines only guide their signals, and that the power lines do not radiate.[35] Aside from violating basic laws of physics, let us agree that if there were no radiation from wires (especially really short wires), then there would be no need for the Part 15 regulations covering unintentional and incidental radiators – they wouldn't radiate!

It is not only the NTIA measurements and analysis that indicate there may be a severe problem between BPL and the amateur community. BPL systems have been installed in a number of other countries where they are referred to as PLC (Power Line Communications) or PLT (Power Line

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[31] The weeks of interference experienced by licensee W0SR are reported in a number of filings. The most complete technical one is Spencer (JUN 2004).

[32] Ameren (JUN 2004) at 17, Current Technologies (AUG 2003) at 24, APPA (JUN 2004) at 5, Southern (JUN 2004) at 24.

[33] NPRM at ¶44. Note also the provisions of §15.113 (b) which call for power line carrier systems to select operating frequencies to achieve the highest practical degree of compatibility with licensed users.

[34] §15.3 (f). Are all BPL systems transmitting RF energy by conduction? If so, where is the return path for the non-differential systems?

[35] Current Technologies (AUG 2003) at 21

Telecommunications). CEPT[36] conducted a number of studies and measurements on the effects on radio services due to cable and LAN systems.[37] This report shows interference to shortwave broadcasting and amateur communications is possible with levels that are below those of Part 15. However, much of the analysis is done under the assumption that the PLC source does not raise the noise floor by more than 0.5 dB[38], which is rather severe, as this is the protection level given to safety-of-life systems. However, field testing typically recorded the quasi-peak field strength values (which is what Part 15 requires) as well as subjective listening tests with actual receivers. The report mentions that a number of the measurements exceeded existing standards, although most manufacturers have reported they will meet the standard limits. Figure 1 shows proposed European limits versus frequency. Most of these standards follow the slopes for environmental noise so that a constant signal-to-noise is presented to the victim receiver. Many trial systems are built to meet the German Usage Provision 30 or NB30 limits, the most liberal of these proposals. The Part 15 limits (converted to the 3 meter measurement distance of these standards) is shown as proposal number 5 in the report, as it was the limit offered by the PLT community. The comment from Report 24 on this stated: "The application of example n°5 limits or the CISPR radiated limits would mask the level of amateur radio operation almost completely or even obliterate it. These limits may be justified in certain cases for small-band emissions, typical for analogue equipment only."[39]

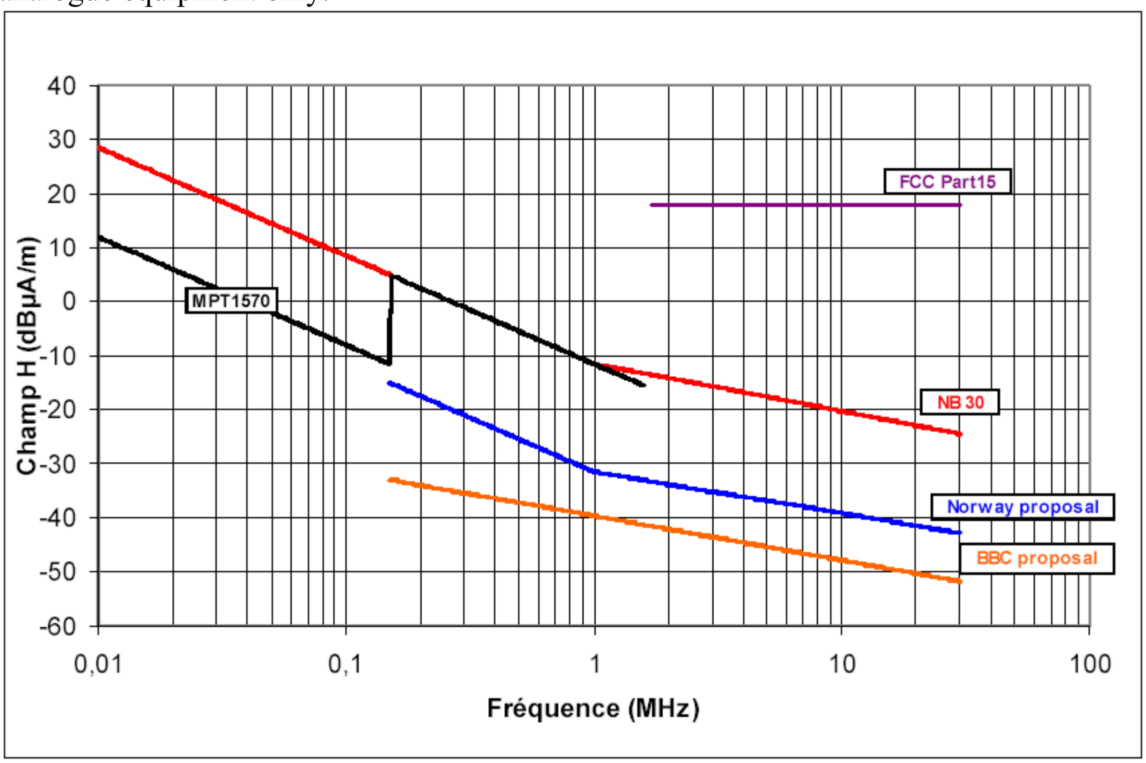

Figure 1 Proposed European limits. From ECC Report 24, Annex 6

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[36] Actually the ECC (Electronic Communications Committee) of CEPT (the European Conference of Postal and Telecommunications Administrations).
[37] ECC Report 24.
[38] This is an interference-to-noise ratio of –10 dB (see Technical Appendix, figure 2).
[39] ECC Report 24 at §9.4.4.2

A number of BPL proponents[40] have opposed the NTIA proposal that prior coordination take place to protect certain sensitive government installations. The argument generally follows that this forces them to act like a licensed service without any of the benefits of one. However, there is already precedence for this as exemplified by §15.242(e), §15.307, and §15.525. Since the BPL system (containing a multiplicity of devices) will exist over a reasonably well-defined, fixed region, one questions how much of a burden this really is. Isn't the period when the system is being designed the best time to avoid problems, rather than rolling the system out to discover you are causing interference?

The Tragedy of the Commons

To this point, I have only spoken directly about the issues affecting amateur operations. Needless to say there are a number of other users of the spectrum who could also be adversely impacted. Shortwave listeners are another group that, because of their likely location in the midst of a residential area, may suffer the same kind of interference effects. Southern[41] has stated, "By the very nature of high-frequency radio propagation, the signals are influenced by seasonal variations, sunspots and even the time of day. In addition, the signals are subject to interference from the shortwave stations themselves, several of which may operate on the same or adjacent frequencies. In short, unlike domestic broadcasting, where stations operate on discrete, protected frequencies, shortwave reception can be a very hit-or-miss proposition." Southern has obviously not paid attention to shortwave broadcasting for a decade or more. Shortwave broadcasting is allocated spectrum and frequency assignments are coordinated through ITU because it is known that there are seasonal variations. This means that twice a year a new schedule is produced that also takes into account the varying characteristics of the sun spot cycle. In addition, many shortwave stations transmit in multiple frequency bands to ensure coverage to various parts of the world.

Domestic broadcasters like WGST (640 AM - Atlanta) would probably like to be protected from other stations on their frequency like KTIB (Thibodaux, LA) and WJNA (Ft. Lauderdale) but are probably less concerned about WRUR (Rochester, NY) – who is probably worried about CFYI (Toronto). The truth is that frequencies are reused, they don't obey national borders, and channels are not even assigned the same way in every country – protection is just a matter of degree. Southern further states[42] "...the wider availability of broadband Internet access to a growing user community must be given precedence over any extreme measures that would be needed to preserve the interests of a dwindling constituency". Just throw away your shortwave radio and buy a computer is not a viable financial option for many – merely running high-speed signals down the street does not eliminate the digital divide. This is hubris in the extreme! By analogy, Southern not only asks that we turn over our public park to them, so that they can build a farm on it and reap the benefit of the harvest, but they offer to capture all the birds and the bees and put them in a small sanctuary that we can visit – for a fee. Considering how Southern feels about the 1.2 million shortwave listeners in the U.S. I wonder how they feel about the 680,000 amateur radio operators.[43] No wonder that the two sides are at loggerheads.

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[40] Duke (June 2004) at 19, PLCA (June 2004) at 4, Southern (June 2004) at 35

[41] Southern (AUG 2003) at 18-19

[42] *Id.* at 19.

[43] Actually, I don't need to wonder. Southern (JUL 2003 at 14) attempts to blacken the reputation of countless amateurs by implying that interference to poorly designed receivers was in fact the fault of the amateur, and because

Signal Ingress

A number of filers[44] have expressed concern about the issue of amateur signals upsetting proper operation of BPL systems. BPL devices operate under Part 15 and must not only ensure no harmful interference is caused but also must accept interference.[45] The question is what will happen to a BPL device in the presence of a strong RF field? Southern[46] has stated "…BPL is intended as a broadband network for packet communications where a lost data packet can be retransmitted with little disruption". A lofty goal, but what happens, for instance, to a Voice over IP conversation in a densely populated BPL system when packets are lost over an extended period of time? The AMRAD tests[47] showed BPL devices had an extreme sensitivity to in-channel and even adjacent channel signals. Improved receiver design may help[48], but absent band-reject filters on the inputs to BPL devices, the likelihood of device upset seems high if there are amateur stations located nearby – an increased likelihood if BPL expands across the country.

The concerns of most amateurs is well stated by ARRL in a response to proceeding ET 03-65: "The Commission has derived great comfort in the past from the regulatory requirement of Part 15 that unlicensed RF devices must accept any interference received from authorized radio services -- even that which might cause malfunction of the Part 15 device. However, that regulatory provision is virtually useless to the consumer, who has purchased the device or system without advance notice of that fact, as a practical matter, and without notice that its interference susceptibility makes its proper operation conditioned on the happenstance of its operating environment (which is outside the capacity of the consumer in most cases to control). The result, since the cause and effect of RFI to consumer electronics is not intuitively obvious to non-technical consumers, is that the transmitter operator is blamed in every case." Or more simply, as Tom O'Hara[49] has observed, "Tell that to the 300 lb ex-linebacker next door..." Imagine what the situation becomes when it is not one consumer, but a few blocks of them.

From a wider perspective, what will happen when it is 6.8 million customers against 680,000 amateurs? I have had friends threatened with "the FCC", community councils, and lawsuits over issues due to poor receiver or audio equipment immunity.[50] I have had neighbors that have experienced some sort of problem ask me if I am the cause, when I haven't even been operating – all you need is an easily visible antenna and you are a likely suspect for any electronic equipment malfunction. I had a friend (whose station was examined by the FCC and given a clean bill of health) who had "quiet hours" imposed on him because his neighbor wanted to keep watching his old TV with the 21 MHz IF. A recent announcement in Australia indicated that the

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no one is suggesting that all amateurs be shut down, it's OK for some utility companies to generate interference without having to respond to complaints.

[44] For example: AMRAD (MAY2004); ARRL (AUG 2003) at 19,26,27; Compton at 1.

[45] §15.5

[46] Southern (AUG 2003) at 16

[47] Amateur Radio Research and Development Corporation (MAY 2004).

[48] The FCC initiated a Notice of Inquiry, ET Docket No. 03-65, " Interference Immunity Performance Specifications for Radio Receivers", in MAR 2003.

[49] "So.Calif. ATV Standards and Practices", Tom O'Hara, W6ORG

[50] see also NTIA report TR-03-404 "Receiver spectrum standards: Phase 1 - Summary of research into existing standards", July 2003.

ACA was considering holding the amateur operator responsible for fixing any problems with interference. Although this has now been modified, there are other parts of the world where unlicensed operations are starting to be given the authority of a secondary or even primary spectrum user. This has been especially true with regard to wireless networking systems where, for example, WRC 2003 allocated the mobile service a primary allocation in the 5 GHz (U-NII) band. What guarantees are provided that BPL won't be raised to this level at some point in the future?

Adaptive Interference Mitigation

The NPRM, NTIA, and some BPL proponents[51] have suggested that adaptive interference mitigation techniques can be employed to automatically reduce power or frequency content to avoid harmful interference to radio services based on the presence of strong signals. Aside from questions as to what would be appropriate time constants for the engagement and release of certain frequency controls, the issue is one of receive-only operations. As mentioned above, the amateur operator scans a band listening for relatively weak signals before transmitting, while the shortwave listener is always receiving. With an adaptive BPL system, they may not be able to hear anything, as the system does not think any spectrum users are present. This also ignores similar problems resulting from the use of in-band or cross-band repeaters[52], operations between amateurs located in different ITU Regions that may require offset frequency operations due to international agreements, and the use of propagation beacons or other one-way systems. The ability to null out certain portions of the spectrum at particular BPL devices can be a powerful tool for interference mitigation, but only in a pre-planned, or remote-controlled type of operation, not as an adaptive technique, because the signals that need protection are the weak ones, not the strong ones.

Equipment authorization

The problem with Access BPL (and to a lesser extent, In-house BPL, due to its use of the closely spaced wires of typical code-approved cabling) is that testing the device itself is not adequate to determine the field strength that might result in any particular installation. It may be possible for a manufacturer to perform enough testing to ensure any unit they produce will not generate excessive field strengths in any installation, or to determine what settings will guarantee compliance for particular configurations (buried, elevated, one wire, three wire, three wire plus neutral, LV from the transformer, LV twisted to the home, etc…). There is little to indicate in this proceeding that enough has been learned about these systems to do anything other than test each system *in situ*. Arguments about "professional" installation hold little water here – power linemen installing BPL injectors are no more likely to be RF engineers than homeowners who need merely insert a HomePlug appliance into the wall outlet. I urge the Commission to proceed slowly here until adequate data on full-sized systems has been obtained to indicate that approval can be based on measurement of just three systems. I see no particular advantage to holding the operators responsible for compliance of the individual devices used in system. This does not mean that they are relieved of their responsibility to ensure there is no harmful interference. The

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[51] NPRM at ¶40, NTIA Report 04-413 at 8-2, Ambient (JUL 2003) at 8.

[52] The term repeater, in the amateur service, implies a device that receives on one frequency and retransmits the received audio signal on another frequency (or frequency band). Variations on this include translators in the amateur satellite service, which retransmit the RF signal on a different band without demodulation, and the digipeater, which stores incoming digital messages on one frequency, to retransmit them at a later time on the same frequency.

distinctly different nature of broadband BPL compared to other carrier current systems argues for some form of special treatment in the rules, whether it be additional paragraphs or subsections within Part 15.

Unintentional emitters are usually authorized by verification[53]. The problem with this is that no record is filed with OET and therefore information is not available through the OET Equipment Authorization System website. In fact, a search for Grantee Code often returns no information, while even with a Grantee Code in hand a search of the database seldom returns matches for BPL equipment[54]. Information about the frequency characteristics of particular systems is of more value to me in evaluating interference risk or causality then a publicly available nationwide database (which the proponents seem to oppose) that lists the geographic location of all BPL devices. Very few people have a spectrum analyzer to do detailed analysis of signals, but many amateur receivers have wide frequency coverage and some are equipped with "band scopes", a diminutive version of a spectrum analyzer. Using such equipment and knowing the spectral limits of a device might help verify if it was a likely source of interference.

Measurement

NTIA has performed a large number of measurements on existing BPL trial systems as well as electromagnetic simulations of a section of a BPL system[55]. BPL proponents seem to be upset that the results of the measurement campaign were not presented as field strength and that there may be issues with how the testing was conducted.[56] NTIA has provided much insight as to measuring techniques for Access BPL and it would appear that an approach that would provide reasonable results while minimizing effort would be one where measurements are performed 1 or 2 meters above the ground and about 10 meters from the lines with slant range to the BPL device or lines being recorded as range, and adding a correction factor for height. Absent any more convincing data, the 5 dB height correction suggested by NTIA seems appropriate. Since most EMC testing is performed with equipment designed to operate over a wide range of frequencies, it does not appear that measurements at sequentially incrementing frequencies should be any more of a chore than pushing a single button. NTIA suggestions for various distances down the length of the transmission line seem to be onerous to proponents, so I suggest the following alternative: Measure at the FCC recommended positions and if the height corrected equivalent signal at 30 meters is within 1 dB of the standard, then repeat with closer spacing between points to ensure that a peak has not been missed. In the case that the high measured point was at the furthest point from the BPL device, then the measurement distance should be extended to ensure a peak has not been missed.

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[53] See NPRM at ¶44.

[54] I realize that Access BPL systems are currently under experimental license. But a search for In-Home BPL devices has only resulted in data on Corinex Global Corporation equipment. A search for Phonex did not return any data, although they have been selling In-Home carrier current devices for a number of years. Most of the information I have on the spectral characteristics of HomePlug compliant devices has come from foreign sources.

[55] NTIA (JUN 2004) and NTIA Report 04-413 "Potential Interference From Broadband Over Power Line (BPL) Systems To Federal Government Radiocommunications At 1.7 - 80 MHz Phase 1 Study", APR 2004

[56] Ambient (JUN 2004) at 3, Ameren (JUN 2004) at 6,7, Southern (JUN 2004) at 26,27. It is interesting to note that there is a dearth of similar data from operators of experimental Access BPL, who have had much more time, and should have, as part of their experimental license, made many measurements to ensure their compliance with the rules. See also Technical Appendix.

Recommendaations
Given that some form of BPL will be authorized, the first issue will be one of eliminating interference. If BPL and the amateur community are going to be able to coexist in residential areas, it will only be because of a cooperative effort. Current Part 15 levels do not provide adequate protection to HF users in reasonably close proximity to a BPL system, so it is unclear to me that there will always be a solution to the problem. Thus, reduced operating levels, at least in particular frequency bands, will be required in some, if not all, installations. If all BPL devices do not have these features installed, then the service provider will have to replace or relocate interfering devices to mitigate interference. If BPL devices are to be verified, not certified, then there should be some means of providing a publicly accessible database of device spectral characteristics similar to what the Commission has recommended. For Access BPL this database may need to be specific to a service provider if they have programmed their devices to avoid certain frequency bands. This should reduce the number of interference complaints that are not due to neighborhood BPL devices while calming the fears of power/BPL companies from revealing the locations of every device. A geographic indicator of the coverage area (corners, center/radius) need be the only entry to indicate a region that has Access BPL installed. NTIA continues to do testing to resolve some of the issues raised in their initial round of testing, and I can only hope the Commission will withhold any rulemaking until after their final reports are in. Calls for increasing power limits for Access BPL not only fly in the face of evidence of the risk of interference it presents, but against recommendations from other parts of the world. Increasing Access BPL power limits is not only premature but provides proponents with an advantage they continually claim should not be given to their competition. Little has been said about handling problems between In-House and Access BPL interference problems and how they will be resolved. It appears that the homeowner needs to be supplied with some filter mechanism to keep Access BPL from interfering with In-House BPL. Will there need to be a filter supplied to the power customer to eliminate interference to radios and TVs due to Access BPL or In-House BPL coming down the service line, and will installing this filter at the entry point into the dwelling be sufficient, or will it need to be at the pole? These are questions yet to be resolved.

Technical Appendix

Background

The basic gauge of signal quality in the amateur service is the RST (Readability-Strength-Tone) report. In this system, a strength value of S-1 means "Faint signals, barely perceptible", while a value of S-9 means "Extremely strong signals". At some point, someone decided that a meter should be provided for a receiver that would eliminate the guesswork in determining the strength, and thus we have the S-meter. It is commonly agreed that S-9 represents a signal level of 50µV at the antenna terminals of the receiver and that each "S-unit" represents a signal decrease of 6 dB (half of the voltage). This places an S-1 signal 48 dB below S-9 at approximately 0.2 µV. At a reasonably quiet site and with good propagation conditions, it is possible to receive and understand signals well below 0.2µV.

Interference Potential

The limiting factor for most MF through low VHF receivers is not the noise floor of the receiver, but the ambient noise present in the environment. At 10 MHz and below, atmospheric noise (lightning) is typically the limiting factor, while man-made noise (from motors, engines, Part 15 devices, etc…) is the limiting factor above 14 MHz. The figure below shows the expected field strength of noise versus frequency from man-made and atmospheric contributions.

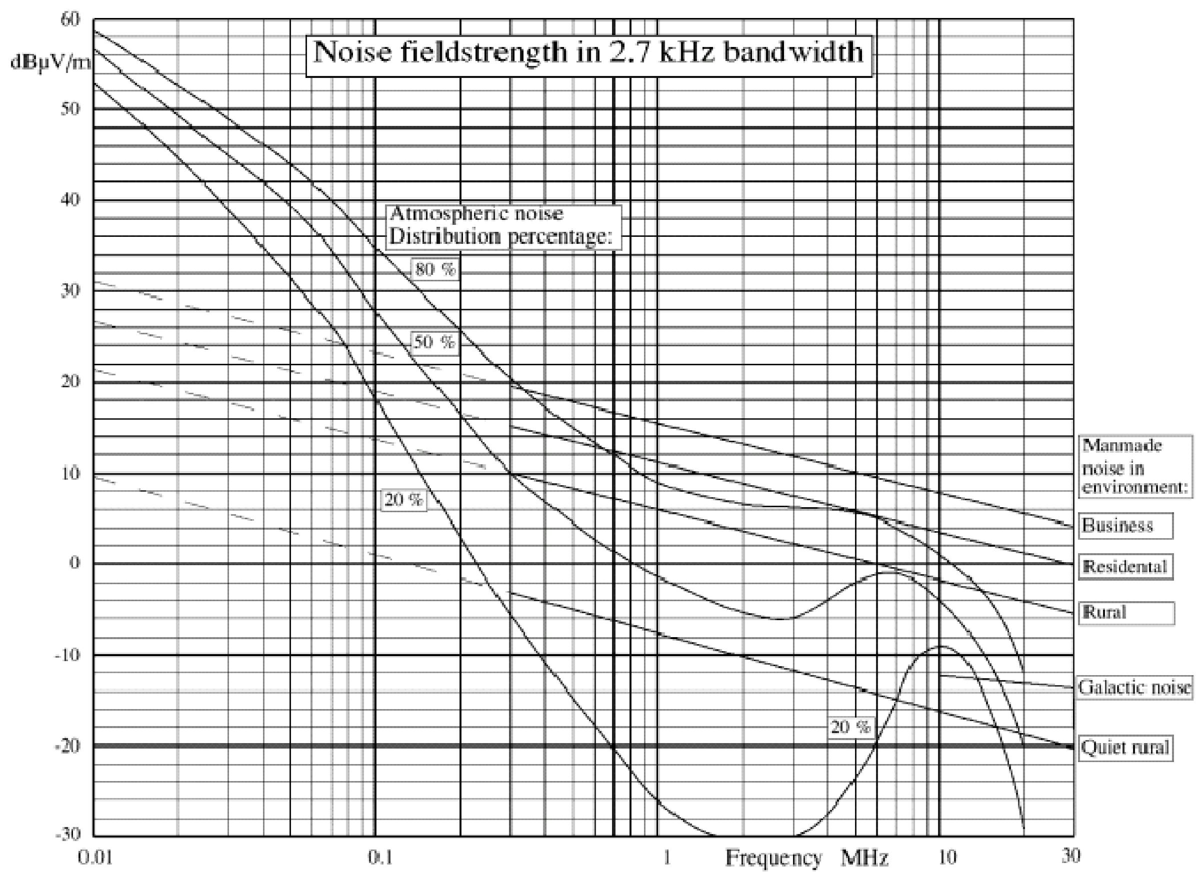

Figure 1 Figure 1. Noise Field Strength versus Frequency[1]

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[1] From Appendix B, ERC Report 69, "Propagation Model And Interference Range Calculation For Inductive Systems 10 KHz - 30 MHz"**,** February 1999

We further simplify the analysis by assuming an isotropic antenna for the victim, realizing that may underestimate the range at which interference could be a problem if a gain antenna is used. Note that the values in figure 1 are expressed as field strength in dBμV/m in a 2.7 kHz bandwidth, a bandwidth typical of amateur SSB radios. This makes it easy to calculate the increase in background noise level that would occur 30 meters from a Part 15 device that just meets compliance requirements. We also assume[2] the BPL signal has the same characteristics as Gaussian noise and correct for the differences in bandwidth between the 9 kHz measurement for Part 15 and the 2.7 kHz bandwidth of the receiver. The Part 15 requirement is 29.5 dBμV/m and the bandwidth ratio reduces this by 5.2 dB to 24.3 dBμV/m. Using the residential curve for man-made noise at 14 MHz (the band in the middle of the expected BPL frequency range), we see the expected noise is 2 dBμV/m, 22.3 dB below the level of the BPL signal. Certainly, this level can be considered harmful interference. Figure 2 shows the effective noise floor, relative to the expected background noise floor, for various BPL noise levels. Note that for this case, even if we were to reduce the BPL signal by 22.3 dB, the effective noise floor would still be 3 dB worse than ambient.

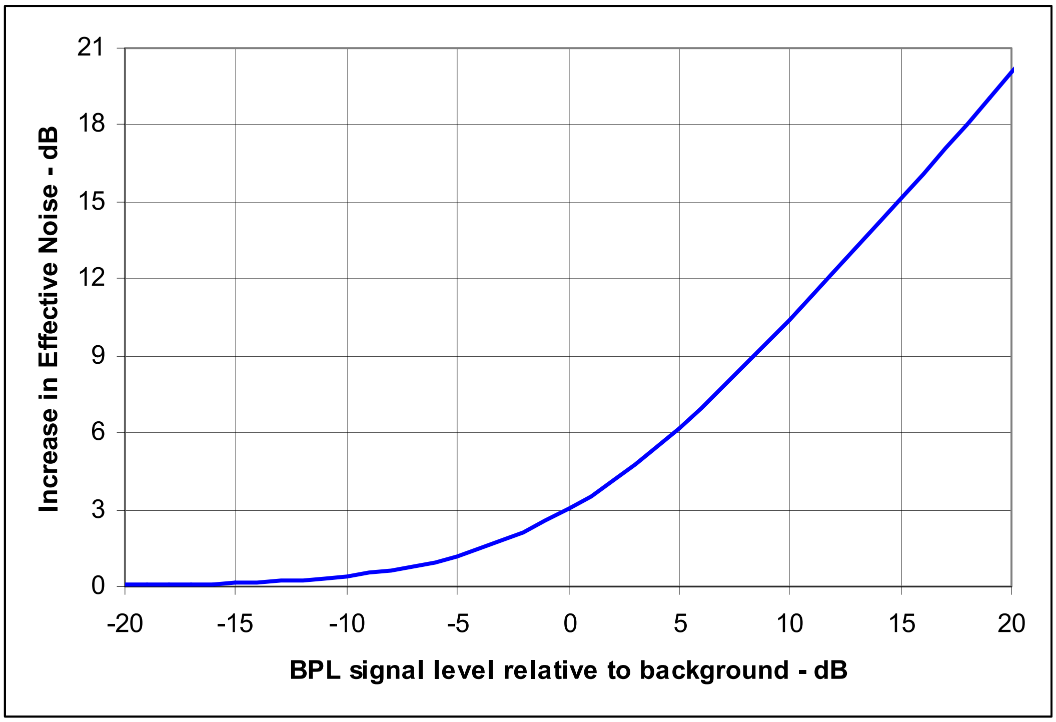

Figure 2 Increase in noise due to BPL signal

At what range does the BPL signal continue to be a problem? If we assume a $1/R^2$ field strength change versus range[3], then increasing the range to 100 meters will produce a 20.9 dB reduction in the signal level, or approximately a 5 dB increase in the effective noise floor. Please note that these calculations are for a single frequency band, and for a specific population density. Interference potential will vary depending on these parameters as well as the antenna actually

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[2] This is a reasonable assumption for the systems that have been presented, and at worst, underestimates the interference potential.

[3] This is the FCC recommendation. As we will see later, this underestimates the field strength here.

used. Mitigation techniques such as band notching and power reduction may minimize the interference potential.

Would this really be a problem in a residential setting? Figure 3 shows a layout of a section of a typical[4] residential community. If the BPL transmitter (injector, repeater, extractor) is located on the pole near the house, all of the antennas are less than 30 meters distant. Even if the injector is 4 houses away, the antennas are within 100 meters.

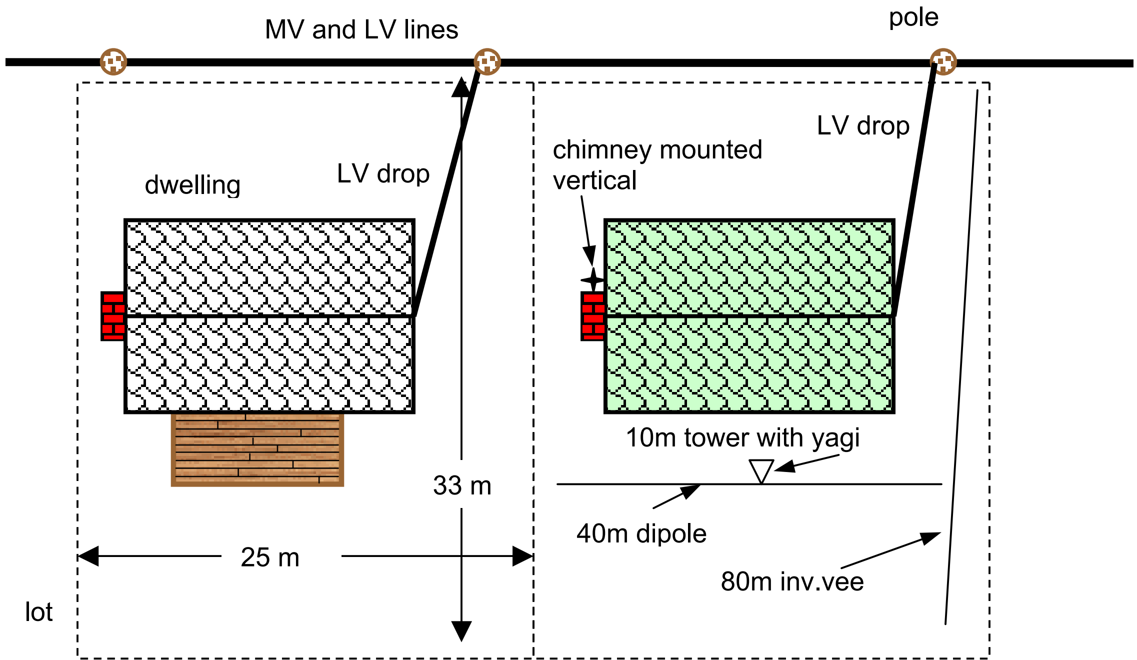

Figure 3. Example of a residential setting where antennas can be close to power lines

This does not consider what may happen with the LV lines should they be carrying BPL signals to the home. While the emissions are hopefully lower with the typical twisted feed used on most LV drops to house, some antennas may be in close proximity to these lines[5] (or the lines running through the house).

Southern[6] seems to have a problem with the NTIA's characterization of 50% of the receivers within 310 meters of a BPL device suffering a 3 dB reduction in their signal to noise. They base this on an expected free-space loss of 50 dB. However, that is not appropriate in this case, for the issue is what is the signal at 310 meters given that the signal is at the FCC limit at 30 meters. For instance, if we look at a quiet rural site at 20 MHz, then the noise floor is driven by atmospherics and is approximately -11 dBμV/m. We apply the $1/R^2$ correction to the BPL field strength for a

[4] The National Association of Realtors reports (in "Land Use and Land Loss in the United States - The Impact Of Land Use Trends On Real Estate Development" 2001) the median lot size for the year 1999 to be 8750 sq ft. The 25×33 meter lot depicted in the figure is 8875 sq ft.

[5] This is not an outrageous configuration. My lot is very close in size to the lots shown above. The large trees on my property on are the same side of the house as the LV drop, as pictured above. I have an 80/40m trap inv. vee, a 30m inv vee, and a 17/12m multiwire inv. vee in those trees.

[6] Southern (JUN 2004) at 27

change from 30 meters to 310 meters and get –11 dBµV/m, the same level as the environmental noise. Referring back to figure 2, we see that the signal to noise is degraded by 3 dB, the same value reported by NTIA[7].

If we move closer than 30 meters the BPL signal level will increase, exacerbating the interference problem. How much more protection do we need if we are only 10 meters from the BPL device? First, we note that the approximation of a $1/R^2$ field strength change versus range would overestimate the interference potential[8]. This is best seen in the results of a simple electromagnetic model[9] of an excited power line. We use a single horizontal wire of 12mm diameter at a height of 10 meters. The wire is 300 meters long and has a current source at its center to simulate a BPL device[10]. Figure 4 shows the change in near-field strength at points 1 and 10 meters above the ground as you move away from the BPL device normal to the line. The dotted lines are a logarithmic (straight-line on this graph) fit to the data. The equations for the average rate of change of signal indicate approximately 35 dB/decade for the 10 m high case and 37 dB/decade for the 1 m high case. These values compare well with the CISPR 18-3 value of 33 dB/decade for measuring powerline noise. Using the CISPR value[11] means the level at 10 meters can be expected to be 15.7 dB higher than the 30-meter level, or 40 dB above the environmental noise floor. If a 14 MHz antenna were located 10 meters from a BPL device, you would need 40 dB of "notching" to mitigate the interference problem on this band.

Radiation from a line

Various BPL proponents have argued that power lines don't radiate, or don't radiate well, and that the totality of power injected into the power lines is merely conducted to the eventual customer. If this is true, then there will be no signal emanating from the line, and the devices in use will not have any problem meeting the Part 15 radiated limits. However, physics and the record reveal these lines do radiate[12]. It is argued[13] that the lines support TEM waves and act as waveguides so that radiation only takes place at junctions or discontinuities along the line. However, this is not the guided wave that exists on a Goubau line where the field is constrained to the insulation around the wire, but is rather the field that exists between the wires or from the wires to ground. The lines may act as wave antennas[14] but Balanis[15] points out that only if they

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[7] NTIA actually used 15 MHz and 25 MHz for this particular analysis and they report a probability based on the density of users in particular EM background conditions (urban/rural, springtime median atmospheric).

[8] See also NTIA Report 04-413 at 7-5.

[9] All EM models are run using EZNEC+ 4.0, a variant of the NEC method of moments code, with a real ground with a dielectric constant of 13 and a ground conductivity of 5 mS/m (EZNEC® is a registered trademark of Roy W. Lewallen). It is not the intent here to provide an exact model of any existing power delivery system, as that would require a very large simulation space that included not only the power lines themselves, but all the nearby conductors, certainly including any other wires on the poles. Rather, then intent is to provide an indication of the trends in signal variations for various changes in parameters.

[10] This could be implemented with a ferrite transformer, where the power conductor is a single "turn" in the center of a split ferrite tube designed to fit over the cable and the secondary winding is where the BPL device connects to inject current into the line.

[11] Note: If anything, this underestimates the level of interference.

[12] For a simple explanation of why currents in wires radiate, see: Keigo Iizuka "Antennas for Non-Specialists" *IEEE Ant. & Prop. Magazine*, **46**-1, FEB 2004, pp.65-84

[13] Ameren (AUG 2003) at 2, 3.

[14] Ameren (AUG 2003) mentions the Beverage antenna, a type of wave antenna, in footnote 6.

[15] Constantine Balanis, *Antenna Theory - Analysis and Design*, John Wiley and Sons Inc., New York 1982

are slow wave structures does radiation takes place only at non-uniformities, curvatures, and discontinuities. For a line to act as a traveling wave antenna, it needs to be terminated to eliminate reflections, for if there are reflections then the wire acts as a standing wave antenna, and should be treated more as a dipole.

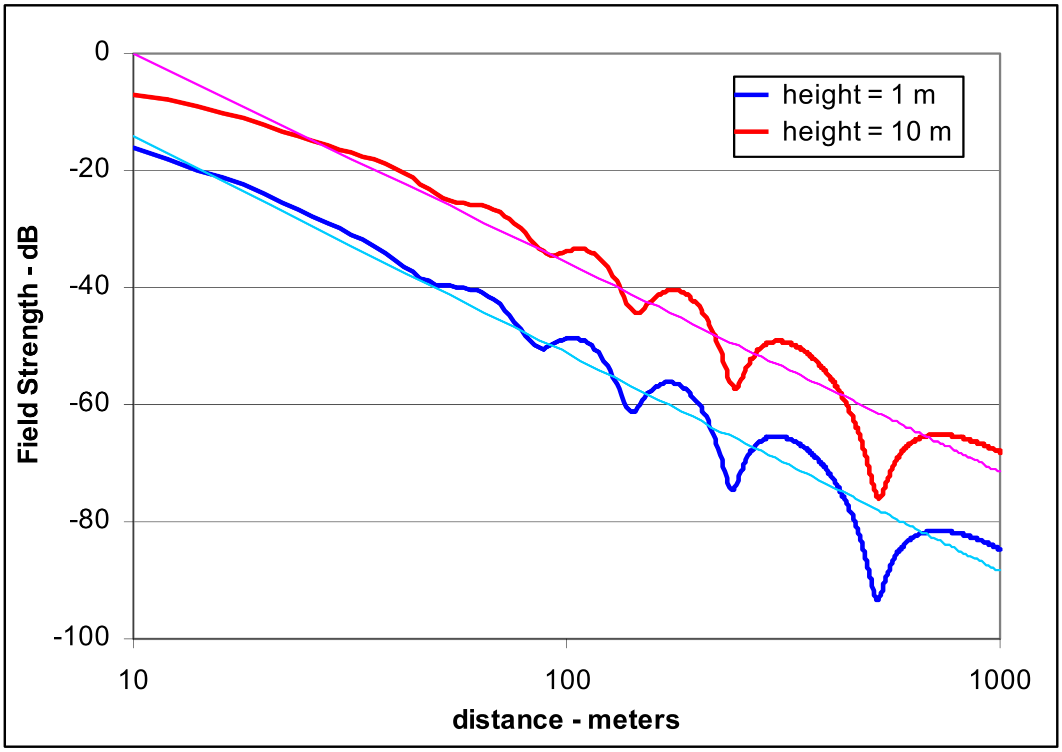

Figure 4. Signal Strength versus Range

Ameren and PowerComm use a differential drive in their BPL implementation, which should minimizes radiation compared to common mode or single wire injectors. However, most of their analysis is based on ideal models of uniformly thin wires of infinite extent (or properly terminated in the surge impedance of the line) that are excited by signals that travel in one direction as per the analysis in D'Amore and Sarto[16]. This paper develops the theoretical solution to this generic problem, and it does show that the vertical field if effectively nulled directly under the wires in the case of differential drive.[17] However, this paper also shows that off to the side of the cables the field increases, and that even when there are two wires driven differentially, there is still a field from the wires to the lossy ground below. This field is stronger in the case of a single wire (or multiple common wires) being excited, as the field exists only between the wire and the ground below. The fact that the analysis is done on a per unit length (pul) basis belies the radiation only at discontinuities. King[18] also points out that for an antenna close to the earth that radiation is a property per unit length, different from an antenna in air, and that this property holds true even for the properly terminated Beverage antenna.

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[16] M. D.Amore & M.S. Sarto, ."Electromagnetic field radiated from broadband signal transmission on power line carrier channels",. *IEEE Trans. Power Delivery*, **12**-2, APR 1997, pp. 624-631.
[17] *Id.,* figures 9 (c) and 9 (d), p.629.
[18] King, R. "The Wave Antenna for Transmission and Reception", *IEEE Trans. Ant. & Prop.*,**31**-6, NOV 1983

Sarto[19,20] expands on the earlier work to include bi-directional propagation of the signal in multiple lines with idealized non-radiating terminations as well as systems that have multiple junctions of multiple line systems. She points out that lossless transmission lines over perfectly conducting ground generate TEM waves but that over poorly conducting ground the longitudinal and transverse fields can have a magnitude on the order of the vertical field. It is noted that the single wire-to-ground injection still has a larger radiated field, but in the more complex arrangements of power networks (still simplified compared to the real world) the radiation from differentially driven systems shows points where it increases. Some of the things that influence this are items that affect that unbalance the differentially driven lines.[21] This can include additional neutral wires, other phases, junctions, variations in conductor size, variations in mounting heights, etc…The problem is that in the real world there are a number of other things that can unbalance the lines including the presence of other unconnected items such as: ground wires, guy wires, high and low voltage feeders on the same pole, and telephone wires. Often, as is the case on my block, the MV lines are split into single phases to service an area of the community and thus are no longer differential. In addition, the impedance of the lines is not well controlled, and varies with load, thus changing the nature of standing waves along the lines in a dynamic sense, and along with that, the pattern of the field.

Current Technologies[22] insists that their system radiates from a point, not a line. As proof of this they offer a single measurement made underneath a line with a BPL device attached to it. There is no indication of what the polarization of the received signal is, but after a large number of simulations (some examples are in figure 5) and examination of NTIA test results, it would appear to be the horizontally polarized electric field. A single wire injected with a BPL signal will continue to exhibit a reasonable vertical field strength to ground along its length if it has enough energy at that point to still be acting as a carrier current transmitter. The rate of change of the field strength is Current Technologies' proof that the signal is a point source. However, the oscillatory nature of the field suggests that a line (whose length exceeds one wavelength) is also radiating. The only explanation for this recorded behavior would seem to be that the BPL injector is inefficient enough, or is severely impedance mismatched, so that a major source of the recorded emissions is actually coming from the wires that connect the BPL device to the line coupler and only a fraction of the device power is actually being transferred to the power line.

Measurements

A number of BPL proponents were concerned with the quality of the NTIA measurements, largely because the results were not specified as field strength. The instrumentation that is available for EMI testing does not measure field strength directly, and usually doesn't directly measure received power either. The instruments are basically tunable RF voltmeters (receivers) with either calibrated detector modules or internal software that will present answers in dBm or

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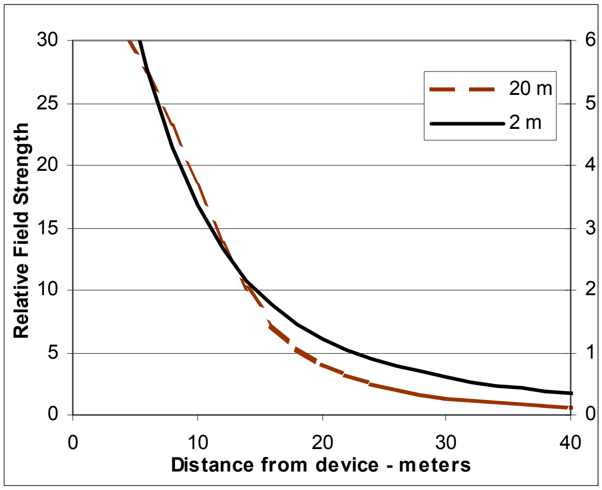
[19] Sarto, M.S. "Electromagnetic Interference from Carrier Channels on Finite-Length Power Lines Above a Lossy Ground in a Wide Frequency Range", *IEEE Trans. Power Delivery*, **13**-2, APR 1998, pp. 336-343

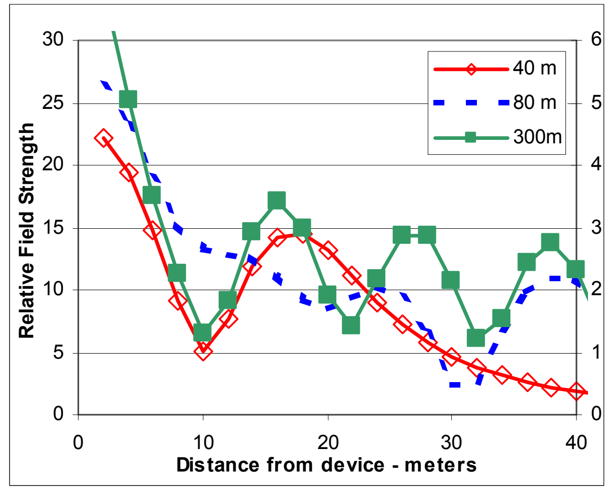
[20] Sarto, M.S. "Time Domain Analysis of Electromagnetic Interference from Broadband Digital Signal Transmission on Finite-Length Power Networks", *IEEE Trans. Power Delivery*, **13**-4, OCT 1998, pp. 972-978

[21] Olsen, R.G., "Technical Considerations for Wideband Powerline Communication - A Summary", *2003 IEEE Int'l Symp. EMC,* Istanbul, pp. 1186-1191

[22] Current Technologies (AUG 2003) at 2, 10.



(a)



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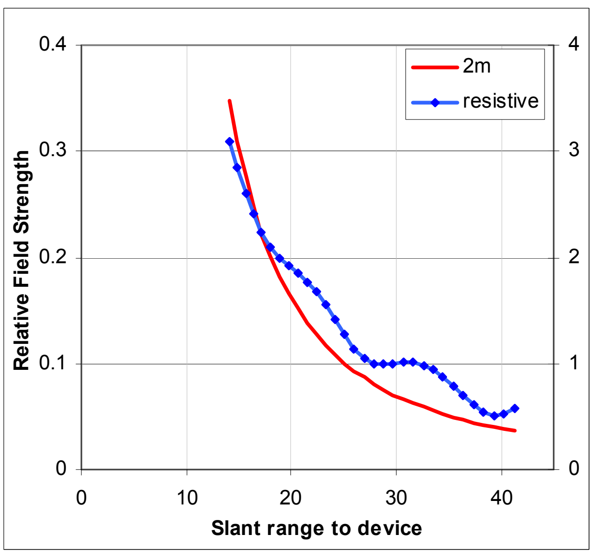
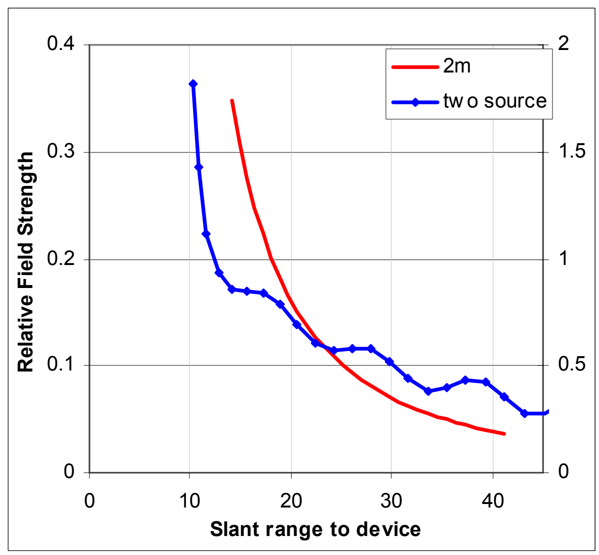


(c)

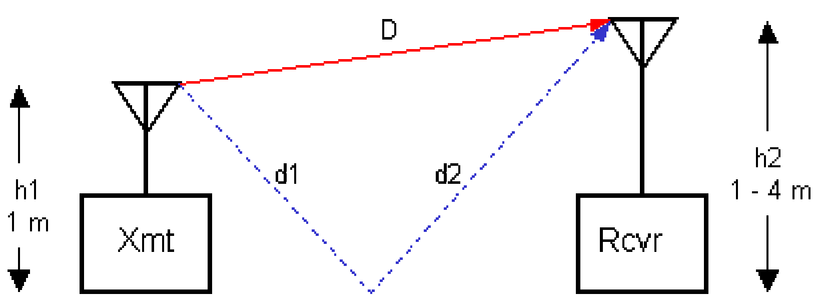


(d)

Figure 5. Models of vary line length with a 14 MHz (λ=21 meter) excitation. (a) shows a "point" (2m long) and a short radiator (20m long). Longer radiators are shown in (b), where the increased length begins to generate phase additions and cancellations from the field along the line. A 300 m line is used in (c) and (d) and the current profile is modified to try and produce a result similar to the Current Technologies plot. In (c) discrete resistors are inserted at 5% length increments to replicate a high loss line, while in (d) a 3 m line is connected to one source while a co-phased source of one-tenth the amplitude drives the line.

dBμV. Some even allow the user to input the antenna factors so they can internally calculate the corrections necessary to present results like field strength, but this is really nothing different then a test operator applying such corrections in a tabular form or in a spreadsheet program. So the issue is just having the data for the antennas used. The effective height of the standard 1.04 m rod antenna is 0.5 m[23] so the field strength in microvolts per meter is equal to twice the applied voltage in microvolts.[24] Other factors will apply to the other antennas used, but the intent of using the vertical antennas was to observe the actual signal levels a victim receiver might encounter in the vicinity of BPL equipment. In any case, the relative measurements made with the same antenna are still capable of showing what the trend in signal strength is, even if the do not answer the question as to whether the absolute field strength meets the Part 15 limits.

There also was concern expressed about the proposed 5 dB correction for making measurements at 1 or 2 meters, versus wherever the peak response actually occurs. The comments ranged from apply no correction to apply a 3.5 dB correction[25]. This is in the face of not just the simulations that show this trend (see also figure 4) but also the measurements of operating BPL in actual power delivery systems. One of the points made is that testing in Europe as reported in ECC 24[26] has not revealed this tendency. A reading of ECC 24 reveals that most testing done was involved with making measurements in the vicinity of homes serviced by PLC, generally not the supply lines, which in many cases were buried. More to the point, the report notes "that the elevation of one extremity can reduce the effective attenuation".[27] The reason for much of the $1/R^2$ field strength rolloff is due to the interaction of the direct wave (D) and the reflected (d1-d2) wave (or in the near-field, the ground wave). This effect is also the basic reason that the test antenna height is varied from 1 – 4 meters in compliance testing as the first peak in a multipath environment *may* occur in this range. This is actually much more likely to occur in the frequency bands above 30 MHz and for testing distances of 10 meters or less. The equipment under test (EUT) is typically set on an 80-cm high non-conducting table so the EUT antenna or chassis is close to 1 m above the ground plane. Large pieces of equipment are placed directly on the ground plane. There is the additional problem that BPL equipment needs to be measured *in situ* rather than at standard test range. Figure 6 shows the geometry involved and the regulating equation.



$$E = 2 \cdot E_0 \cdot \sin \frac{2\pi \cdot h1 \cdot h2}{\lambda D}$$

Figure 6. Typical compliance test setup

The field strength varies in a sinusoidal manner with a minimum at the air-ground interface (where the two signals virtually cancel each other) and a maximum that can have a peak value of

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[23] ANSI 63.5-1998 "American National Standard for Electromagnetic Compatibility - Radiated Emission Measurements in Electromagnetic Interference (EMI) Control - Calibration of Antennas (9 kHz to 40 GHz)" at §7.
[24] ANSI 63.2-1996 "American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz—Specifications" at §15.5.1
[25] Ambient (JUN 2004) at 3; Ameren (JUN 2004) at 5, 6,20.
[26] ECC Report 24 "PLT, DSL, Cable Communications (Including Cable TV), LANS And Their Effect On Radio Services", MAY 2003
[27] *Id.* at 61.

twice the free-space field strength (where the two rays reinforce the signal). This can be seen in figure 7 where the expected field is plotted versus the height of the receive antenna as it is varied from 0.5 to 10 meters. The 30 MHz case has h1 set to 10 meters, with D set to 30 meters, typical of what might be used in a BPL compliance test. The 150 MHz case is for a more typical VHF test where h1 is 1 meter and D is 3 meters and a peak can be found in the 1 – 4 meter height change. Note that this does not occur for the 30 MHz case, where shorter ranges and lower heights would only exacerbate the problem. The problem becomes worse at lower frequencies, but then we are also entering the near field and the two-ray model is not accurate. However, if field strength is falling off as something closer to $1/R^2$ than to $1/R$, then multipath cancellation is taking place.

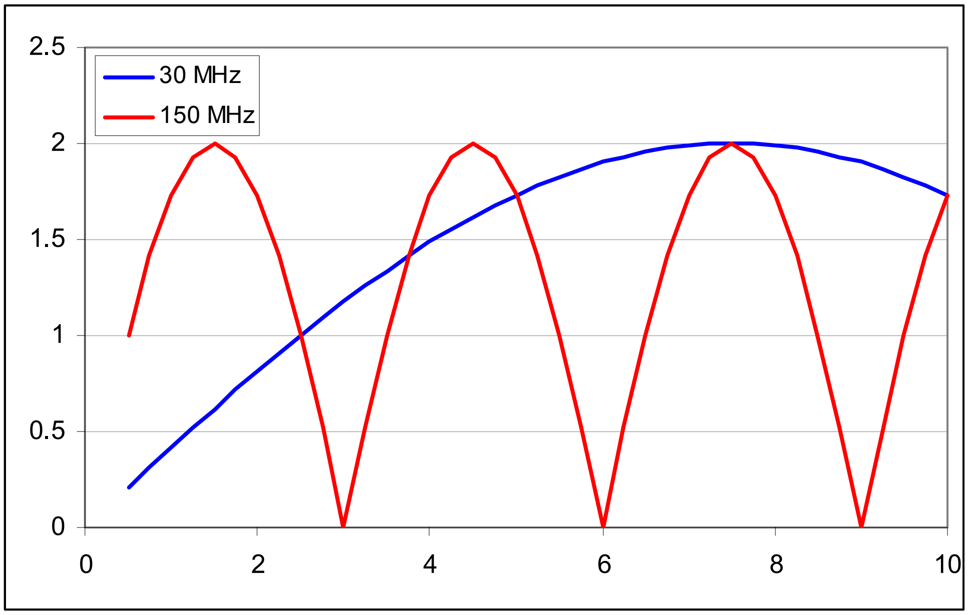

Figure 7 Magnitude of the field strength as receiver height is varied.

Considering the above data, it seems reasonable to consider the NTIA 5 dB correction factor as it appears no one is interested in making measurements at a height of 10 meters at multiple points along a roadway. The problem is that amateur antennas tend to be at heights[28] where the BPL signal is likely to be enhanced from values measured at 1 or two meters and are likely to be in close proximity to LV and MV lines that may transport BPL.

[28] The ARRL website contains a number of unscientific (whoever answered them) surveys that have been conducted in the last few years. One of these surveys indicates that 53% of respondents have their antennas mounted at 39 feet or less. Another indicates that 53% of respondents have antennas that are 100 feet (30.5 m) or less from the nearest power lines with almost 12% reporting they are less than 25 feet (7.6 m) from the nearest power lines.